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Vast's Haven-1 commercial station, planned for low Earth orbit around May 2026 is the only fully independent space station currently planned.
Haven-1 is planned as the world's first standalone commercial space station, a single cylindrical module launched atop a SpaceX Falcon 9, with the station designed for roughly three years of operations in low Earth orbit. The station is sized for small, short missions: internal volume is about 45 cubic meters, compared with roughly 900 cubic meters for the ISS. Vast's plan calls for up to four crew per visit, on several two-week missions, using SpaceX crewed spacecraft for transport.

Haven-1 is intended as a technology and operations pathfinder for a larger modular outpost (sometimes referred to as Haven-2) that could evolve toward an ISS-class commercial complex later in the decade.

Other concepts like Orbital Reef, Starlab, and Axiom's station are in development, but their operational dates are currently targeted for 2027–2030 rather than 2026.

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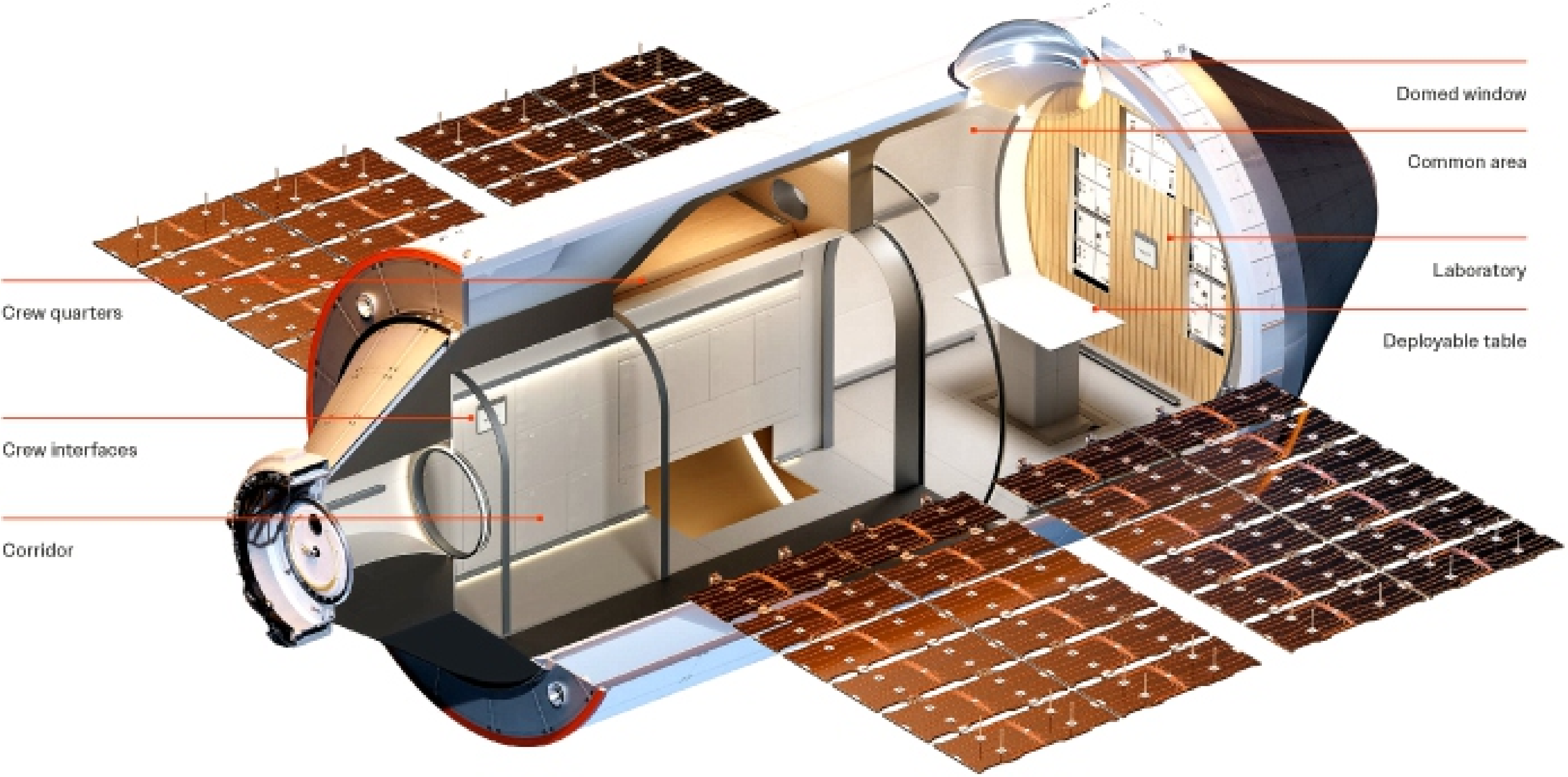

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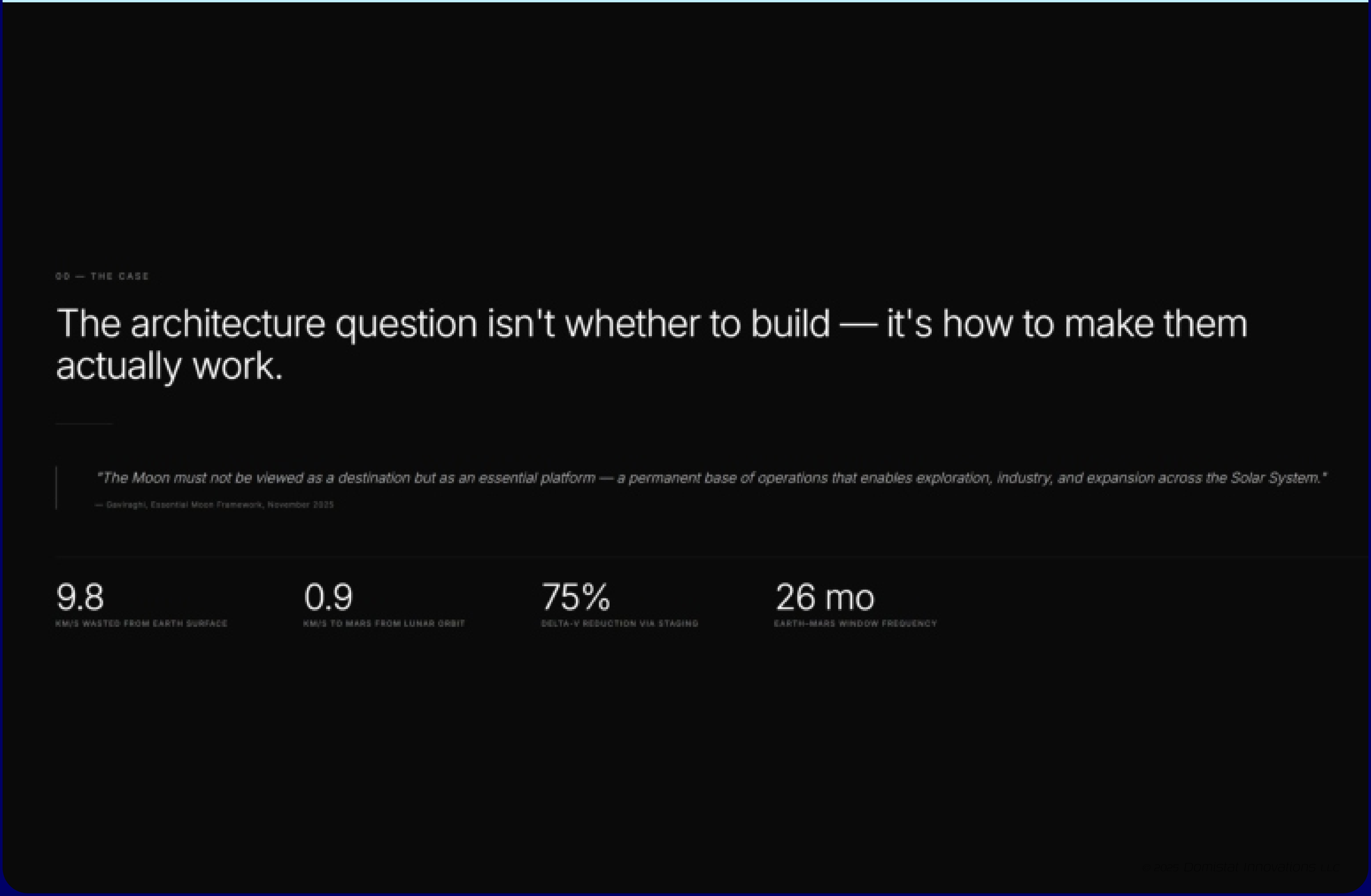
INFRASTRUCTURE · EXOSTRUCTURE · RESEARCH OPINION — APRIL 2026

Space Stations & Moon Bases

A design schema for orbital stations and lunar surface bases as the industrial spine of interplanetary travel — from Haven-1 to Mars departure nodes.

CLASSIFICATION	REVISION	AUTHOR	PRIMARY SOURCE
Infrastructure / Exostructure	1.0 · April 2026	Domistat Innovations LLC	NASA Moon-to-Mars ADD Rev C, Dec 2025



00 — THE CASE

The architecture question isn't whether to build — it's how to make them actually work.

> *"The Moon must not be viewed as a destination but as an essential platform — a permanent base of operations that enables exploration, industry, and expansion across the Solar System."*
>
> — Gaviraghi, Essential Moon Framework, November 2025

9.8	0.9	75%	26 mo
KM/S WASTED FROM EARTH SURFACE	KM/S TO MARS FROM LUNAR ORBIT	DELTA-V REDUCTION VIA STAGING	EARTH-MARS WINDOW FREQUENCY

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01 — PLATFORM TYPOLOGY

Two platforms. One mission.

ORBITAL STATIONS (LEO / CISLUNAR)

Zero-gravity manufacturing, propellant depot operations, crew transfer — without the energy cost of surface gravity wells. Operate in 300–450 km LEO or near-rectilinear halo orbit (NRHO).

→ Haven-1 class: ~45 m³, 4 crew, 2-week rotations
→ ISS-class commercial: ~900 m³, 6–7 crew, long-duration
→ Cislunar Gateway class: ~125 m³ initial module volume
→ Full staging hub: 2,000+ m³, 10–30 crew capacity

LUNAR SURFACE BASES

Trade orbital energy efficiency for in-situ resources. Water ice at the south pole — confirmed at 5–10% by mass — is the propellant that makes the Moon a refueling depot, not a dead end.

→ Minimal outpost: 2–4 crew, 30-day missions
→ Semi-permanent base: 6–8 crew, 180-day rotations
→ Industrial colony: 20+ crew, ISRU-powered continuous ops
→ Nuclear Fission Surface Power: 3 × 40 kW = 120 kW baseline

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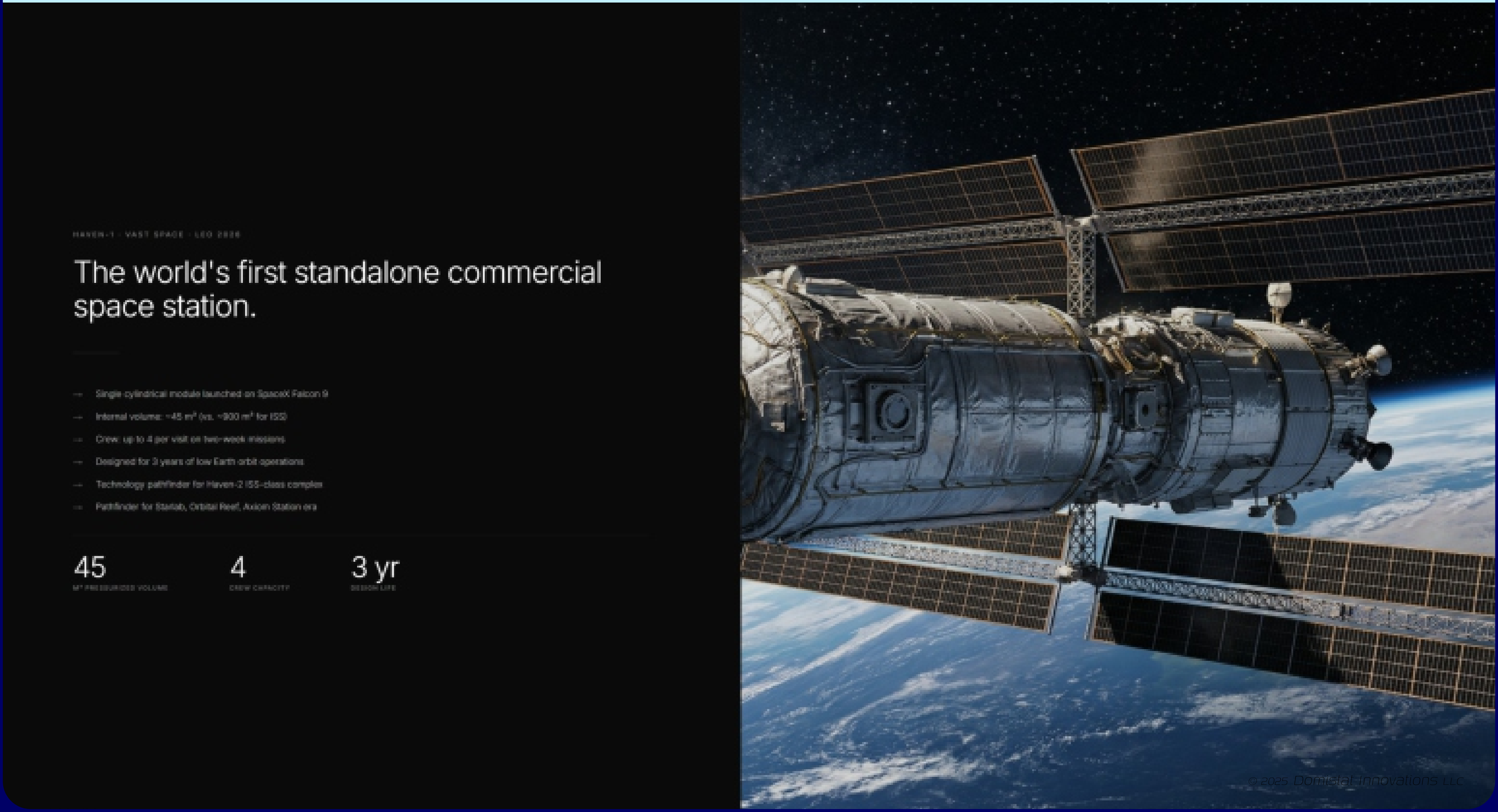

HAVEN-1 · VAST SPACE · LEO 2026

The world's first standalone commercial space station.

- Single cylindrical module launched on SpaceX Falcon 9
- Internal volume: ~45 m³ (vs. ~900 m³ for ISS)
- Crew: up to 4 per visit on two-week missions
- Designed for 3 years of low Earth orbit operations
- Technology pathfinder for Haven-2 ISS-class complex
- Pathfinder for Starlab, Orbital Reef, Axiom Station era

45
M³ PRESSURIZED VOLUME

4
CREW CAPACITY

3 yr
DESIGN LIFE

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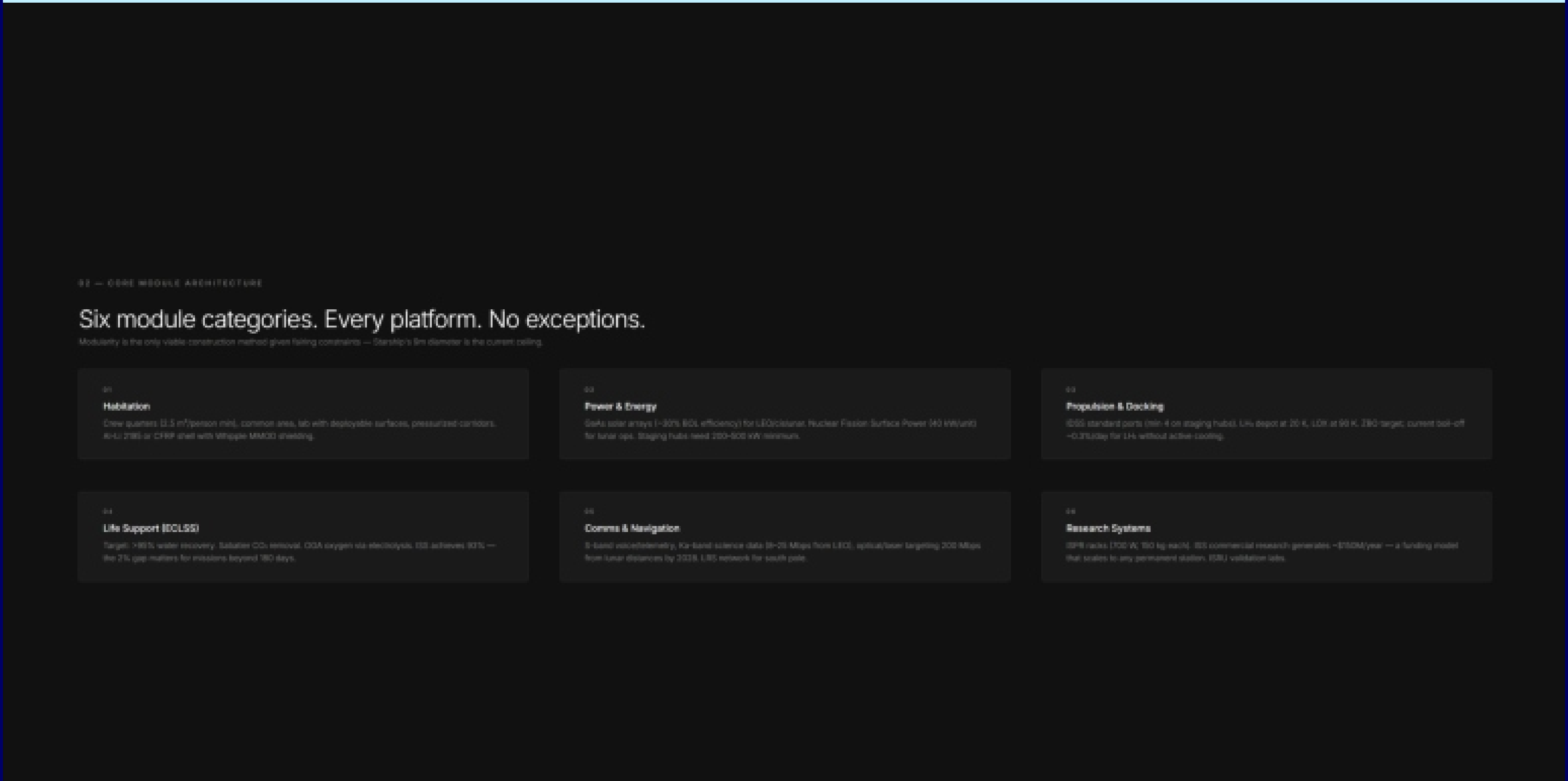


02 — CORE MODULE ARCHITECTURE

Six module categories. Every platform. No exceptions.

Modularity is the only viable construction method given fairing constraints — Starship's 9m diameter is the current ceiling.

01

Habitation

Crew quarters (2.5 m³/person min), common area, lab with deployable surfaces, pressurized corridors. Al-Li 2195 or CFRP shell with Whipple MMOD shielding.

02

Power & Energy

GaAs solar arrays (~30% BOL efficiency) for LEO/cislunar. Nuclear Fission Surface Power (40 kW/unit) for lunar ops. Staging hubs need 200–500 kW minimum.

03

Propulsion & Docking

IDSS standard ports (min 4 on staging hubs). LH_2 depot at 20 K, LOX at 90 K. ZBO target; current boil-off ~0.3%/day for LH_2 without active cooling.

04

Life Support (ECLSS)

Target: >98% water recovery. Sabatier CO_2 removal. OGA oxygen via electrolysis. ISS achieves 93% — the 2% gap matters for missions beyond 180 days.

05

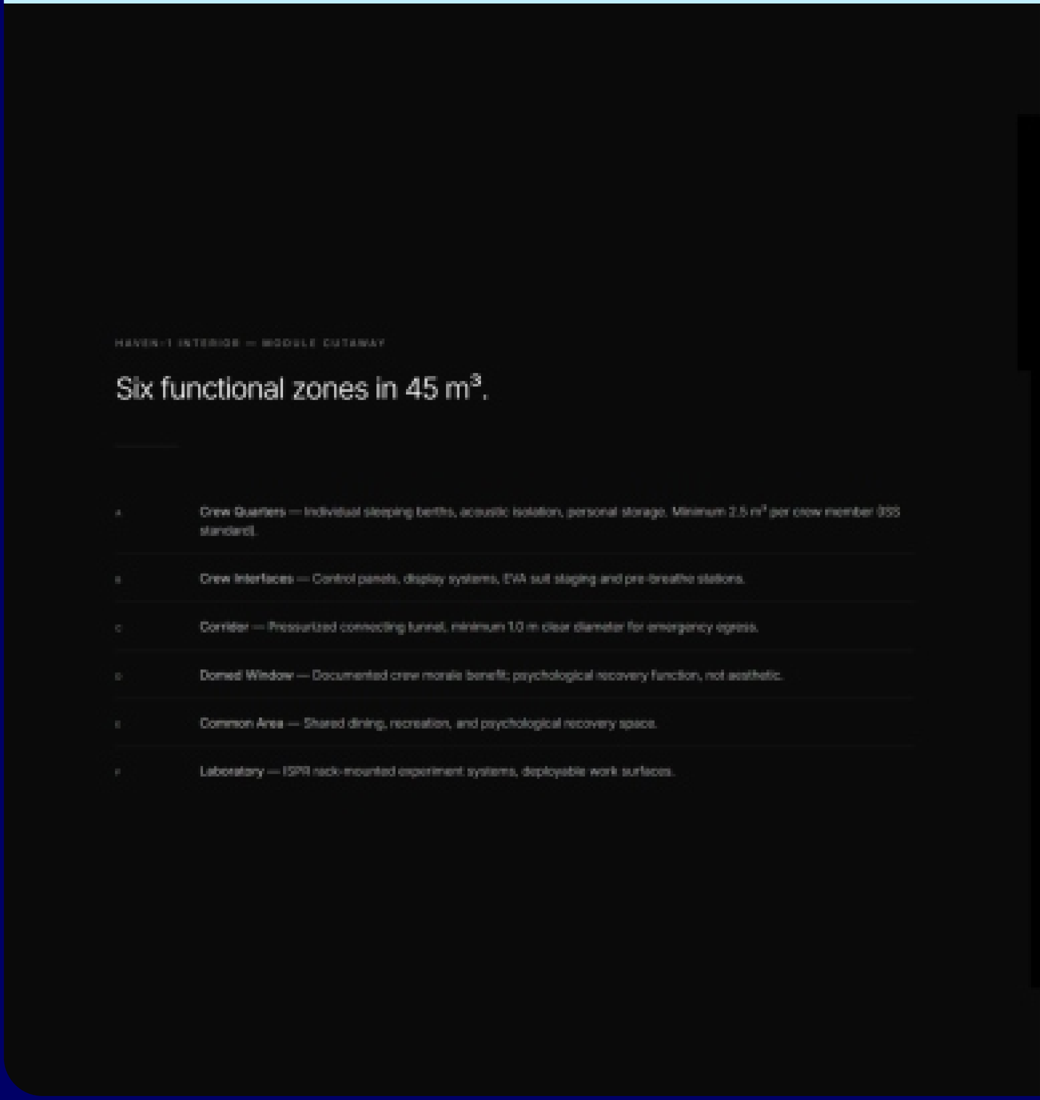
Comms & Navigation

S-band voice/telemetry, Ka-band science data (8–25 Mbps from LEO), optical/laser targeting 200 Mbps from lunar distances by 2028. LRS network for south pole.

06

Research Systems

ISPR racks (700 W, 150 kg each). ISS commercial research generates ~$150M/year — a funding model that scales to any permanent station. ISRU validation labs.



HAVEN-1 INTERIOR — MODULE CUTAWAY

Six functional zones in 45 m³.

A **Crew Quarters** — Individual sleeping berths, acoustic isolation, personal storage. Minimum 2.5 m³ per crew member (ISS standard).

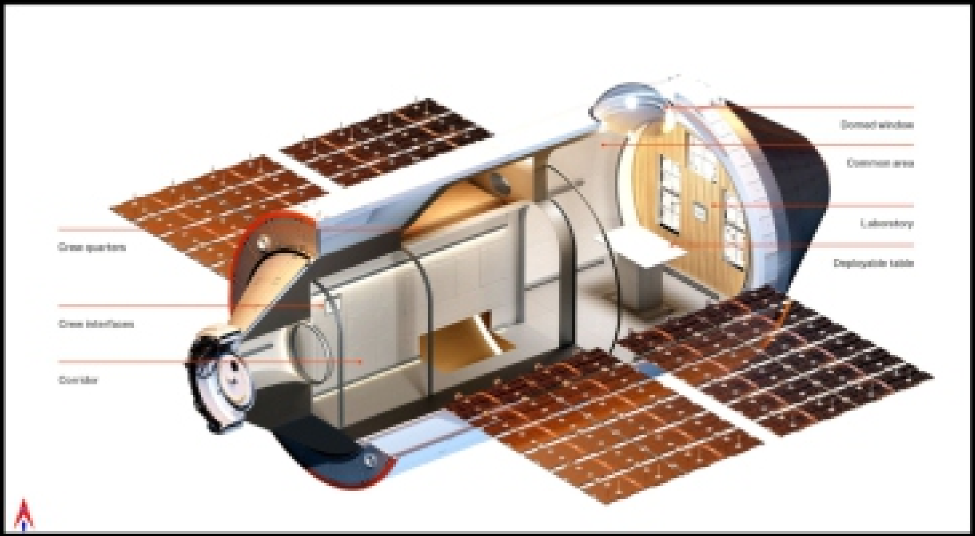
B **Crew Interfaces** — Control panels, display systems, EVA suit staging and pre-breathe stations.

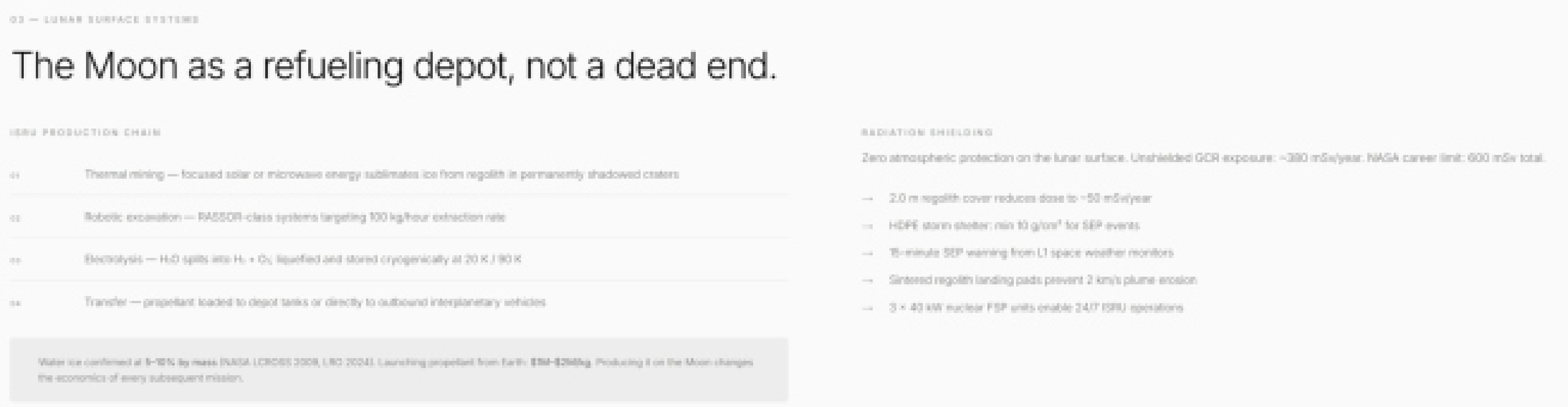
C **Corridor** — Pressurized connecting tunnel, minimum 1.0 m clear diameter for emergency egress.

D **Domed Window** — Documented crew morale benefit; psychological recovery function, not aesthetic.

E **Common Area** — Shared dining, recreation, and psychological recovery space.

F **Laboratory** — ISPR rack-mounted experiment systems, deployable work surfaces.





03 — LUNAR SURFACE SYSTEMS

The Moon as a refueling depot, not a dead end.

ISRU PRODUCTION CHAIN

01 Thermal mining — focused solar or microwave energy sublimates ice from regolith in permanently shadowed craters

02 Robotic excavation — RASSOR-class systems targeting 100 kg/hour extraction rate

03 Electrolysis — H_2O splits into H_2 + O_2; liquefied and stored cryogenically at 20 K / 90 K

04 Transfer — propellant loaded to depot tanks or directly to outbound interplanetary vehicles

Water ice confirmed at **5–10% by mass** (NASA LCROSS 2009, LRO 2024). Launching propellant from Earth: **$1M–$2M/kg**. Producing it on the Moon changes the economics of every subsequent mission.

RADIATION SHIELDING

Zero atmospheric protection on the lunar surface. Unshielded GCR exposure: ~380 mSv/year. NASA career limit: 600 mSv total.

→ 2.0 m regolith cover reduces dose to ~50 mSv/year
→ HDPE storm shelter: min 10 g/cm² for SEP events
→ 15-minute SEP warning from L1 space weather monitors
→ Sintered regolith landing pads prevent 2 km/s plume erosion
→ 3 × 40 kW nuclear FSP units enable 24/7 ISRU operations

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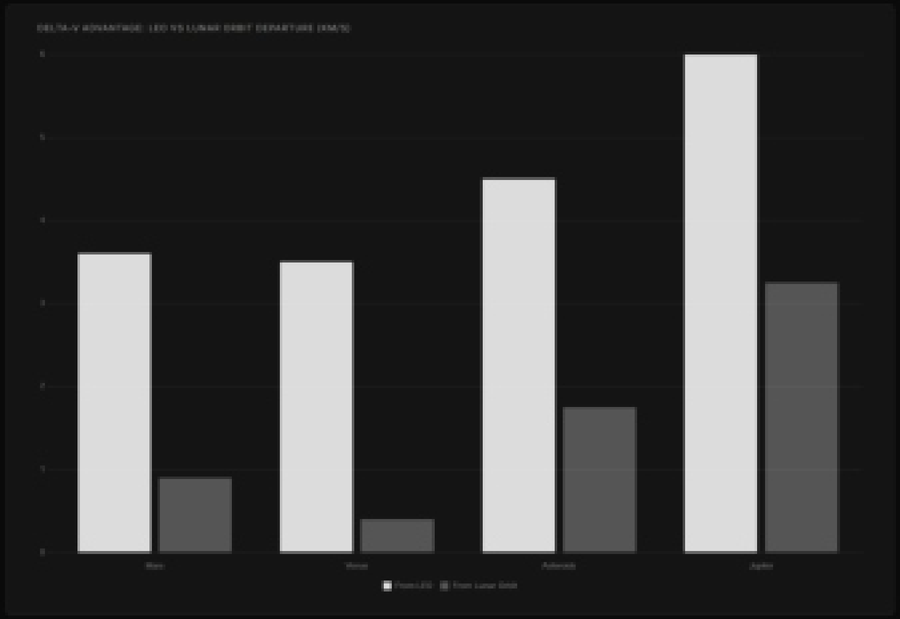
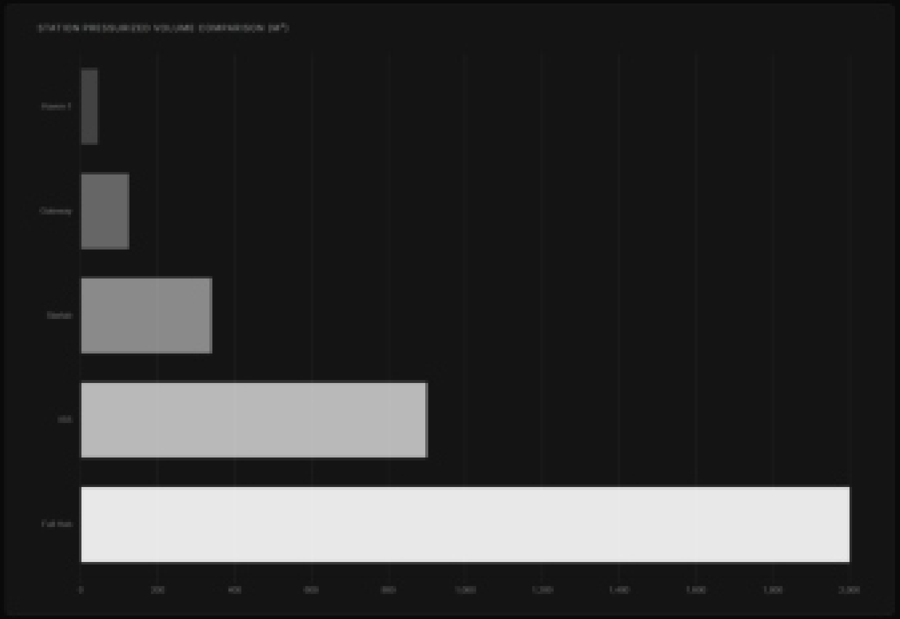
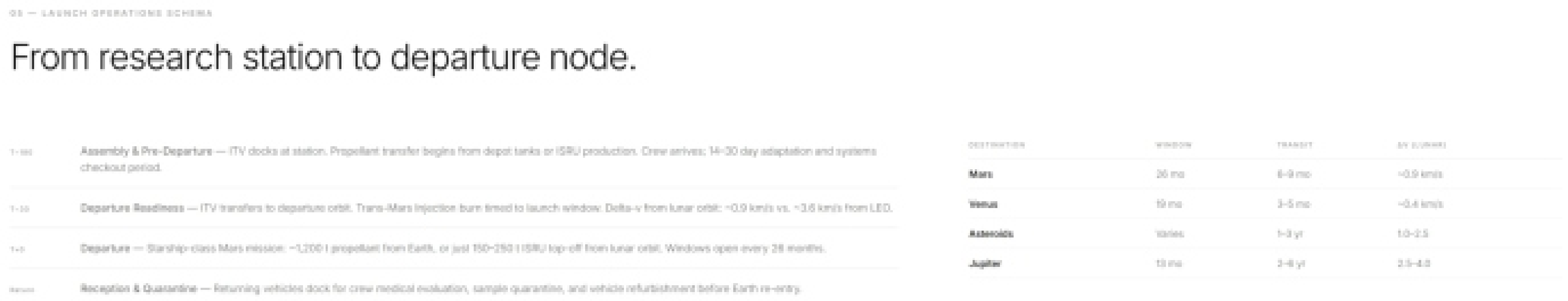
04 — THE NUMBERS

Energy, propellant, and time — the three currencies of interplanetary travel.





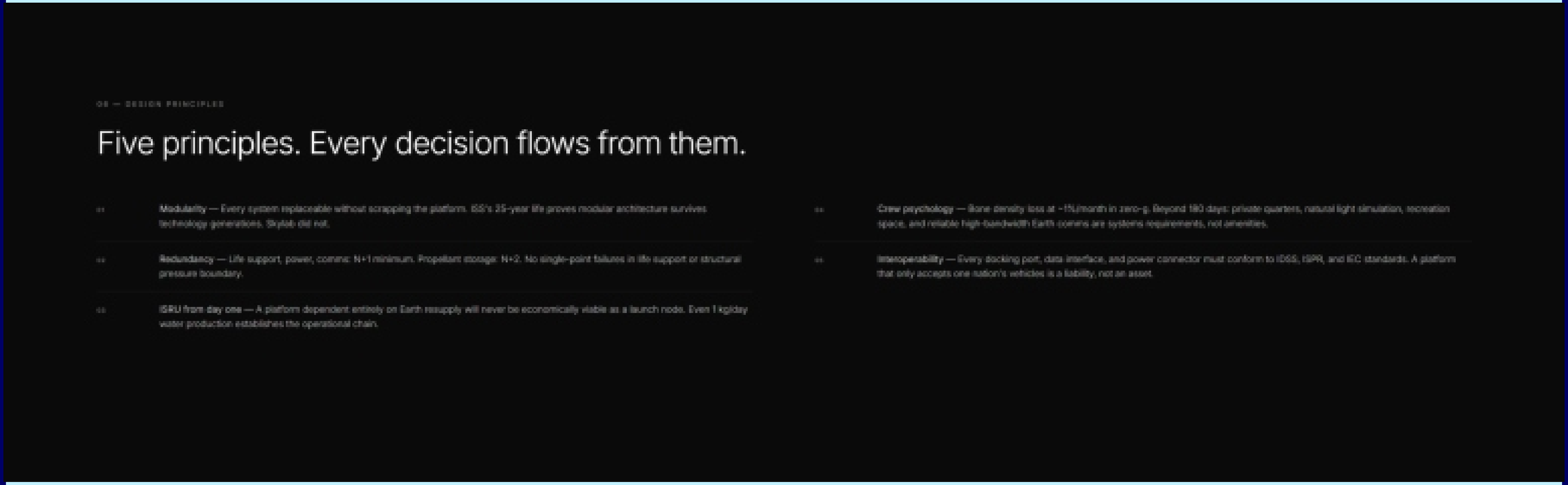


05 — LAUNCH OPERATIONS SCHEMA

From research station to departure node.

T−180	**Assembly & Pre-Departure** — ITV docks at station. Propellant transfer begins from depot tanks or ISRU production. Crew arrives; 14–30 day adaptation and systems checkout period.
T−30	**Departure Readiness** — ITV transfers to departure orbit. Trans-Mars Injection burn timed to launch window. Delta-v from lunar orbit: ~0.9 km/s vs. ~3.6 km/s from LEO.
T−0	**Departure** — Starship-class Mars mission: ~1,200 t propellant from Earth, or just 150–250 t ISRU top-off from lunar orbit. Windows open every 26 months.
Return	**Reception & Quarantine** — Returning vehicles dock for crew medical evaluation, sample quarantine, and vehicle refurbishment before Earth re-entry.

DESTINATION	WINDOW	TRANSIT	ΔV (LUNAR)
Mars	26 mo	6–9 mo	~0.9 km/s
Venus	19 mo	3–5 mo	~0.4 km/s
Asteroids	Varies	1–3 yr	1.0–2.5
Jupiter	13 mo	2–6 yr	2.5–4.0



08 — DESIGN PRINCIPLES

Five principles. Every decision flows from them.

Modularity — Every system replaceable without scrapping the platform. ISS's 25-year life proves modular architecture survives technology generations. Skylab did not.

Redundancy — Life support, power, comms: N+1 minimum. Propellant storage: N+2. No single-point failures in life support or structural pressure boundary.

ISRU from day one — A platform dependent entirely on Earth resupply will never be economically viable as a launch node. Even 1 kg/day water production establishes the operational chain.

Crew psychology — Bone density loss at ~1%/month in zero-g. Beyond 180 days: private quarters, natural light simulation, recreation space, and reliable high-bandwidth Earth comms are systems requirements, not amenities.

Interoperability — Every docking port, data interface, and power connector must conform to IDSS, ISPR, and IEC standards. A platform that only accepts one nation's vehicles is a liability, not an asset.

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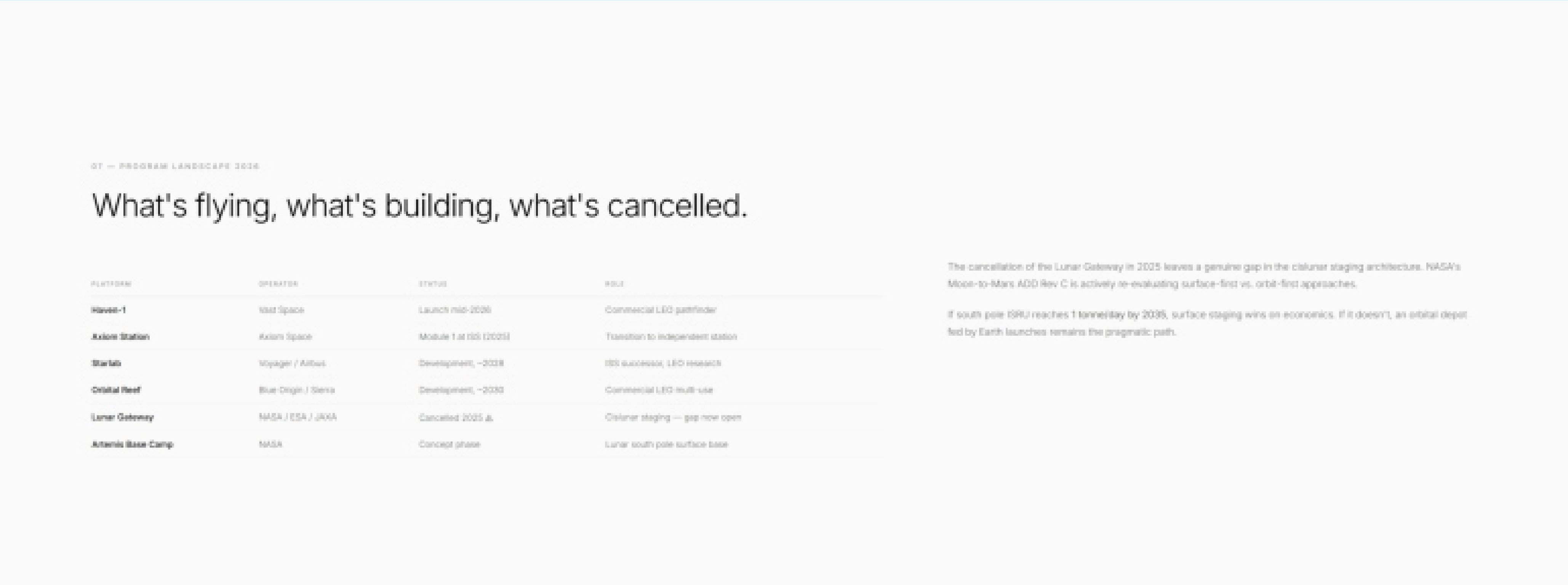

07 — PROGRAM LANDSCAPE 2026

What's flying, what's building, what's cancelled.

PLATFORM	OPERATOR	STATUS	ROLE
Haven-1	Vast Space	Launch mid-2026	Commercial LEO pathfinder
Axiom Station	Axiom Space	Module 1 at ISS (2026)	Transition to independent station
Starlab	Voyager / Airbus	Development, ~2028	ISS successor, LEO research
Orbital Reef	Blue Origin / Sierra	Development, ~2030	Commercial LEO multi-use
Lunar Gateway	NASA / ESA / JAXA	Cancelled 2025 ⚠	Cislunar staging — gap now open
Artemis Base Camp	NASA	Concept phase	Lunar south pole surface base

The cancellation of the Lunar Gateway in 2025 leaves a genuine gap in the cislunar staging architecture. NASA's Moon-to-Mars ADD Rev C is actively re-evaluating surface-first vs. orbit-first approaches.

If south pole ISRU reaches **1 tonne/day by 2035**, surface staging wins on economics. If it doesn't, an orbital depot fed by Earth launches remains the pragmatic path.

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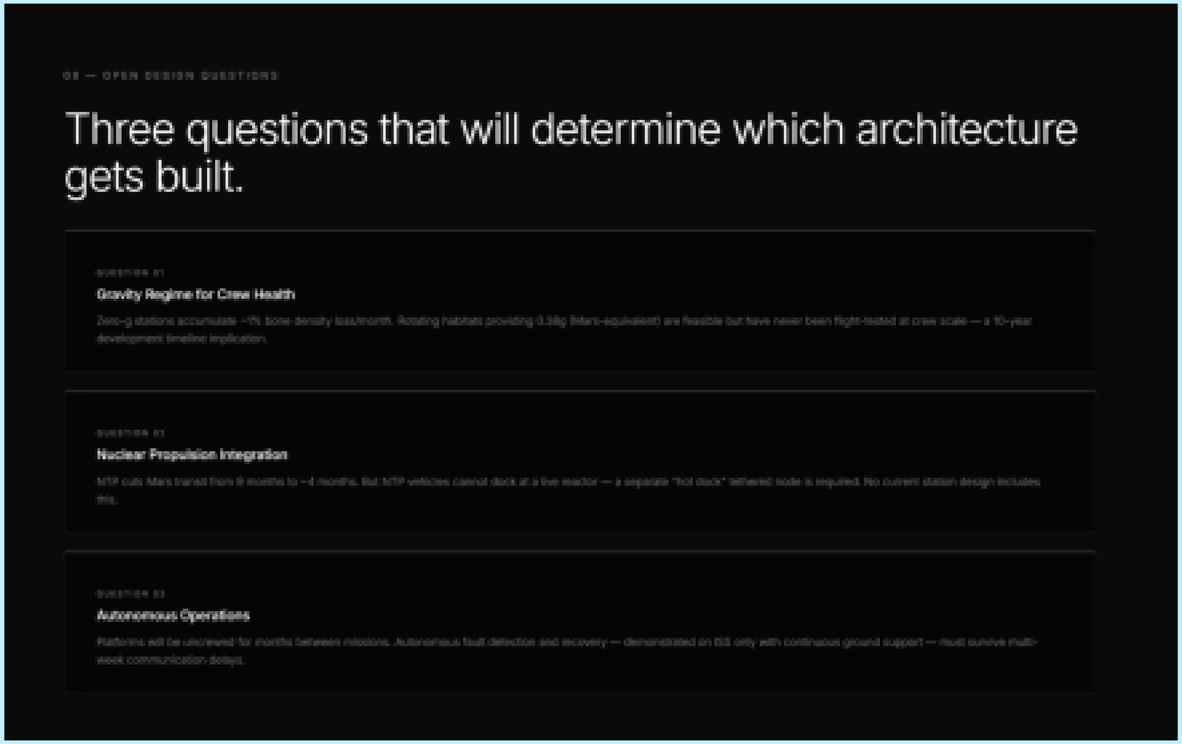

08 — OPEN DESIGN QUESTIONS

Three questions that will determine which architecture gets built.

QUESTION 01

Gravity Regime for Crew Health

Zero-g stations accumulate ~1% bone-density loss/month. Rotating habitats providing 0.38g (Mars-equivalent) are feasible but have never been flight-tested at crew scale — a 10-year development timeline implication.

QUESTION 02

Nuclear Propulsion Integration

NTP cuts Mars transit from 9 months to ~4 months. But NTP vehicles cannot dock at a live reactor — a separate "hot dock" tethered node is required. No current station design includes this.

QUESTION 03

Autonomous Operations

Platforms will be uncrewed for months between missions. Autonomous fault detection and recovery — demonstrated on ISS only with continuous ground support — must survive multi-week communication delays.

THE BOTTOM LINE

The infrastructure is the mission.

Interplanetary exploration does not begin at launch. It begins the day a platform is designed to serve as a departure node — not just a research outpost.

Domistat Innovations LLC · Design Schema Rev 1.0 · April 2026
Sources: NASA Moon-to-Mars ADD Rev C (Dec 2025) · Vast Space Haven-1 (2025) · Essential Moon Framework (Nov 2025) · NASA FSP Program (2024) · NASA HRP Annual Report (2024)

Design Schema: Space Stations & Moon Bases as Interplanetary Launch Platforms

Classification: Infrastructure / Exostructure · Research & Design Opinion

Revision: 1.0 · April 2026

Author: Domistat Innovations LLC

The next phase of human spaceflight demands more than destinations — it demands infrastructure. Space stations in low Earth orbit and permanent bases on the Moon are not waypoints; they are the industrial spine of interplanetary travel. A mission to Mars launched directly from Earth's surface wastes roughly 9.8 km/s of delta-v fighting gravity and atmosphere. The same mission staged from lunar orbit or the lunar surface costs a fraction of that energy budget. The architecture question is no longer whether to build these platforms — it's how to design them so they actually work as departure infrastructure, not just research outposts.

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1. Platform Typology

Two distinct platform types serve the interplanetary launch mission. They share functional requirements but differ in location, gravity regime, and construction logic.

1.1 Orbital Space Stations (LEO / Cislunar)

Orbital stations operate in the 300–450 km low Earth orbit band or in near-rectilinear halo orbit (NRHO) around the Moon — the orbital family selected for the now-cancelled Lunar Gateway and still considered optimal for cislunar staging. Their core advantage is zero-gravity manufacturing, propellant depot operations, and crew transfer without the energy cost of surface gravity wells.

Design Tier: Commercial LEO Station (Haven-1 class) → Modular Cislunar Station (Gateway class) → Full Interplanetary Staging Hub

Tier	Volume	Crew	Mission Role
Commercial LEO (Haven-1)	~45 m³	4	Technology pathfinder, 2-week rotations
ISS-class Commercial	~900 m³	6–7	Long-duration research, crew staging
Cislunar Gateway	~125 m³ (initial)	4	Lunar surface access, deep-space gateway
Full Interplanetary Hub	2,000+ m³ (projected)	12–20	Propellant depot, vehicle assembly, crew transit

1.2 Lunar Surface Bases

Surface bases trade the energy efficiency of orbit for access to in-situ resources — most critically, water ice at the lunar south pole, confirmed in permanently shadowed craters at concentrations of 5–10% by mass (NASA LCROSS, 2009; LRO data through 2024). That ice, electrolyzed into liquid hydrogen and liquid oxygen, is the propellant that makes the Moon a refueling depot rather than a dead end.

Design Tier: Minimal Outpost (2–4 crew, 30-day missions) → Semi-Permanent Base (6–8 crew, 180-day rotations) → Industrial Colony (20+ crew, continuous operations, ISRU-powered)

2. Core Module Architecture

Every platform — orbital or surface — is composed of the same functional module categories. Modularity is not a design preference; it is the only viable construction method given current launch vehicle fairing constraints (Starship's 9m diameter being the current ceiling) and the need for incremental deployment over multiple missions.

2.1 Habitation Module

The pressurized crew environment. Minimum viable design follows the Vast Haven-1 precedent: cylindrical primary structure, internal subdivision into functional zones, structural integration with the exostructure truss.

Key Spaces:

- Crew Quarters — individual sleeping berths, acoustic isolation, personal storage; minimum 2.5 m³ per crew member (ISS standard)
- Common Area — shared dining, recreation, psychological recovery; domed observation window preferred for crew morale (documented benefit in ISS psychological studies)
- Laboratory — deployable work surfaces, rack-mounted experiment systems, EVA tool staging
- Corridor System — pressurized connecting tunnels between modules; minimum 1.0 m clear diameter for emergency egress

Structural Specification:

- Primary shell: aluminum-lithium alloy (Al-Li 2195) or carbon-fiber reinforced polymer (CFRP)
- Micrometeorite and orbital debris (MMOD) shielding: Whipple shield configuration, minimum 10 cm standoff
- Internal pressure: 101.3 kPa (1 atm) or reduced-pressure mixed-gas (70 kPa, 30% O_2) to reduce EVA pre-breathe time

2.2 Power & Energy Module

No platform function — life support, propulsion, communications, ISRU — operates without power. Power architecture determines everything downstream.

Solar Arrays (LEO / Cislunar Stations):

- Triple-junction gallium arsenide (GaAs) cells, ~30% efficiency at beginning of life
- Deployable panel arrays; Haven-1 uses ~20 m² total; ISS uses ~2,500 m² for 75–90 kW average
- Interplanetary staging hubs require 200–500 kW minimum for propellant depot operations

Nuclear Fission (Lunar Surface / Deep Cislunar):

- NASA's Fission Surface Power (FSP) project targets 40 kW per unit, deployable by 2030 (NASA/DoE joint program, 2024 status)
- Multiple FSP units provide redundancy; 3 × 40 kW = 120 kW baseline for a semi-permanent base
- Enables 24/7 ISRU operations independent of the 14-day lunar night

Energy Storage:

- Lithium-ion batteries for short-duration backup (current ISS standard)
- Regenerative fuel cells (RFC) for extended eclipse periods — hydrogen/oxygen cycle, round-trip efficiency ~60%

2.3 Propulsion & Docking Infrastructure

The launch platform function lives here. This module category is what separates a research station from a departure node.

Docking Ports:

- International Docking System Standard (IDSS) — the current interoperability standard across NASA, ESA, JAXA, and commercial providers
- Minimum 4 active docking ports on any interplanetary staging hub: 2 for crew vehicles, 1 for cargo/tanker, 1 for outbound mission vehicle
- Berthing mechanisms (CBM-class) for large cargo modules

Propellant Depot Systems:

- Cryogenic propellant storage: liquid hydrogen (LH_2) at 20 K, liquid oxygen (LOX) at 90 K
- Active thermal control required; multi-layer insulation (MLI) plus cryocoolers
- Transfer lines and quick-disconnect couplings rated for repeated cryo cycling
- Boil-off management: zero-boil-off (ZBO) technology target for long-duration storage; current boil-off rates ~0.3%/day for LH_2 without ZBO (NASA Glenn, 2023)

On-Station Propulsion:

- Attitude control: hydrazine or green propellant (AF-M315E) thrusters
- Reboost / orbit maintenance: Hall-effect ion thrusters preferred for fuel efficiency (Isp 1,500–3,000 s vs. ~300 s for chemical)
- Emergency deorbit capability: hypergolic backup

2.4 Life Support & Environmental Control (ECLSS)

Closed-loop life support is the difference between a station and a spacecraft. The target is >95% water recovery (ISS currently achieves ~93% with the USOS ECLSS, as of 2024) and near-zero atmospheric consumable loss.

Atmosphere Management:

- CO_2 removal: Sabatier reaction preferred (converts $CO_2 + H_2 \rightarrow CH_4 + H_2O$, recovering oxygen)
- O_2 generation: Oxygen Generation Assembly (OGA) via water electrolysis
- Trace contaminant control: activated charcoal + catalytic oxidizer beds

Water Recovery:

- Urine processing: vapor compression distillation → potable water
- Humidity condensate recovery
- Target: 95%+ water recovery rate for missions beyond 180 days

Thermal Control:

- Internal: cold plates, heat exchangers, ammonia coolant loops
- External: radiator panels; ISS uses ~1,500 m^2 of radiators to reject ~70 kW average heat load
- Lunar surface stations add regolith thermal buffering: 2–3 m of regolith provides significant passive thermal mass

2.5 Communications & Navigation

RF Systems:

- S-band: crew voice, telemetry, command (legacy standard, all current stations)
- Ka-band: high-rate science data, video (8–25 Mbps downlink from LEO)
- Optical/Laser comm: NASA's LCOT program targets 200 Mbps from lunar distances by 2028

Navigation:

- GPS/GNSS: effective to ~36,000 km altitude; cislunar operations require autonomous navigation
- Star trackers + IMU: primary attitude determination
- Lunar surface: terrain-relative navigation using pre-loaded digital elevation models (DEMs)

Deep Space Relay:

- Lunar Relay Satellite (LRS) network required for continuous south pole surface coverage — the polar location of ISRU-optimal ice deposits falls outside direct Earth line-of-sight

2.6 Scientific & Research Systems

Research capacity is not secondary to the launch platform mission — it funds operations. Commercial research contracts on ISS generate ~$150M/year in revenue (CASIS, 2023), a model that scales to any permanent station.

Laboratory Configuration:

- International Standard Payload Rack (ISPR): 1.05 m × 0.85 m × 0.71 m, 700 W power, 150 kg mass limit — the baseline unit for all microgravity research
- Deployable work surfaces (as shown in Haven-1 cutaway: fold-out tables, rack-mounted displays)
- External payload platforms for materials exposure, astronomy, and Earth observation

Specialized Research for Launch Platform Context:

- Propellant production validation (ISRU): electrolyzer test rigs, cryogenic storage experiments
- Long-duration human physiology: bone density, muscle atrophy, radiation dose accumulation data — all critical for Mars mission planning
- Closed-loop bioregenerative life support: plant growth systems, algae bioreactors

3. Lunar Surface Base — Additional Systems

Surface bases carry all the module categories above plus three systems unique to the surface environment.

3.1 In-Situ Resource Utilization (ISRU)

The economic case for the Moon as a launch platform depends entirely on ISRU. Launching propellant from Earth to lunar orbit costs approximately \$1M–\$2M per kilogram at current launch prices. Producing it on the Moon from water ice changes the cost structure of every subsequent mission.

Water Ice Extraction:

- Thermal mining: focused solar or microwave energy to sublimate ice from regolith
- Excavation: robotic regolith excavators (NASA Regolith Advanced Surface Systems Operations Robot — RASSOR — target: 100 kg/hour extraction rate)
- Processing: electrolysis to split $H_2O \rightarrow H_2 + O_2$; liquefaction and storage

Regolith Processing:

- Sintered regolith blocks for radiation shielding and structural fill
- Aluminum and iron extraction from ilmenite ($FeTiO_3$) — present at 10–15% by mass in lunar mare regolith
- 3D printing with regolith: NASA/ESA joint research demonstrates compressive strength of 20–50 MPa for sintered regolith structures (2023 analog tests)

Oxygen Production:

- Hydrogen reduction of ilmenite: $FeTiO_3 + H_2 \rightarrow Fe + TiO_2 + H_2O \rightarrow \text{electrolysis} \rightarrow O_2$
- ESA's MOXIE-class reactor concept targets 1 kg O_2/hour per unit; scaled arrays for propellant production

3.2 Surface Mobility & Construction

Pressurized Rovers:

- Extended-range crew transport: 100–500 km operational radius
- Mobile laboratory capability
- Emergency crew return vehicle function

Robotic Construction Systems:

- Autonomous regolith excavation and placement
- Additive manufacturing rigs for habitat extension
- Power and communications cable laying

Landing Pad Infrastructure:

- Sintered regolith pads to prevent rocket exhaust plume erosion — unmitigated plume erosion can project regolith at 2 km/s, threatening all nearby structures (NASA LSII studies, 2022)
- Blast berms and deflector geometry around pad perimeter

3.3 Radiation Shielding

The lunar surface offers zero atmospheric protection. Solar energetic particle (SEP) events can deliver lethal doses in hours; galactic cosmic ray (GCR) exposure accumulates continuously.

Shielding Strategy:

- Minimum 2.0 m regolith cover over habitats: reduces GCR dose rate from ~380 mSv/year (surface) to ~50 mSv/year (NASA estimates, 2024); NASA's career limit is 600 mSv
- Storm shelter: high-density polyethylene (HDPE) lined compartment within each habitat; minimum 10 g/cm² areal density for SEP protection
- Real-time space weather monitoring: dedicated SEP detector array, 15-minute warning time target from L1 monitors

4. Interplanetary Launch Operations Schema

This is the functional core: how a platform transitions from a research and resupply station to an active departure node.

4.1 Mission Staging Sequence

Phase 1 — Assembly & Pre-Departure (T-180 to T-30 days)

- Interplanetary transfer vehicle (ITV) docks at station
- Propellant transfer from depot tanks to ITV: multiple tanker flights or ISRU-produced propellant loaded over weeks
- Crew arrives via commercial crew vehicle; 14–30 day adaptation and systems checkout period
- Final cargo manifest loaded; consumables verified for transit duration + 20% margin

Phase 2 — Departure Readiness (T-30 to T-0)

- ITV undocks and transfers to departure orbit (if launching from LEO station)
- Trans-Mars injection (TMI) burn timed to launch window: Earth-Mars windows open every ~26 months
- Departure delta-v from lunar orbit: ~0.9 km/s to trans-Mars trajectory vs. ~3.6 km/s from LEO (significant propellant saving)

Phase 3 — Return Reception

- Returning vehicles dock for crew medical evaluation, sample quarantine, and vehicle refurbishment
- Platform serves as quarantine facility before Earth return — a function the Lunar Gateway design explicitly included

4.2 Launch Window Constraints

Destination	Window Frequency	Transit Time	Departure Delta-v (from Lunar Orbit)
Mars	Every 26 months	6–9 months	~0.9 km/s
Venus	Every 19 months	3–5 months	~0.4 km/s
Asteroid Belt	Continuous (varies)	1–3 years	1.0–2.5 km/s
Jupiter system	Every 13 months	2–6 years	2.5–4.0 km/s

4.3 Propellant Depot Sizing

A single Mars mission using a Starship-class vehicle requires approximately 1,200 tonnes of propellant for Earth departure (SpaceX estimates, 2024). Staged from lunar orbit using ISRU-produced propellant, that figure drops to 150–250 tonnes of top-off propellant at the station. The depot must hold at minimum 300 tonnes of cryogenic propellant with active zero-boil-off management.

5. Design Principles for Platform-Class Infrastructure

Five principles govern every design decision across both platform types.

Modularity over monolithic design. Every system must be replaceable in orbit or on the surface without scrapping the whole platform. The ISS's 25-year operational life (1998–2024+) demonstrates that modular architecture survives technology generations; the Skylab monolith did not.

Redundancy at every critical node. Life support, power, and communications each require N+1 redundancy minimum; propellant storage requires N+2 given the consequence of catastrophic failure. No single-point failures are acceptable in the life support or structural pressure boundary.

ISRU integration from day one. A platform that depends entirely on Earth resupply will never be economically viable as a launch node. ISRU capability - even at small scale - must be part of the initial design, not a future upgrade. Water production of even 1 kg/day on day one establishes the operational chain.

Crew psychology as a systems requirement. Missions beyond 180 days require deliberate design for mental health: private quarters, natural light simulation, dedicated recreation space, and reliable high-bandwidth communication with Earth. The domed observation window in the Haven-1 design is not aesthetic — it is a documented crew performance intervention.

Interoperability as a non-negotiable standard. Every docking port, data interface, and power connector must conform to international standards (IDSS, ISPR, IEC). A platform that can only accept one nation's vehicles is a liability, not an asset.

6. Current Program Landscape (2026)

Platform	Operator	Status	Role
Haven-1	Vast Space	Launch planned mid-2026	Commercial LEO pathfinder
Starlab	Voyager Space / Airbus	Development, ~2028	ISS successor, LEO research
Orbital Reef	Blue Origin / Sierra Space	Development, ~2030	Commercial LEO multi-use
Axiom Station	Axiom Space	Module 1 attached to ISS (2025)	Transition to independent station
Lunar Gateway	NASA / ESA / JAXA / CSA	Cancelled 2025; architecture under review	Cislunar staging
Artemis Base Camp	NASA	Concept phase	Lunar south pole surface base

The cancellation of the Lunar Gateway in 2025 leaves a gap in the cislunar staging architecture. Commercial operators and NASA's Moon-to-Mars Architecture Definition Document (Rev C, December 2025) are actively re-evaluating whether a surface-first or orbit-first approach better serves the interplanetary launch mission. The answer almost certainly depends on ISRU maturity: if south pole water ice extraction reaches 1 tonne/day by 2035, surface staging wins on economics. If it doesn't, an orbital depot fed by Earth launches remains the pragmatic path.

7. Open Design Questions

Three questions remain genuinely unresolved and will shape which architecture gets built.

Gravity regime for crew health. Zero-g stations accumulate bone density loss at ~1% per month (NASA Human Research Program, 2024). A Mars mission crew arriving after 9 months in transit will be significantly compromised. Rotating habitats providing artificial gravity (0.38g Mars-equivalent) are technically feasible but have never been flight-tested at crew scale. The design choice — accept deconditioning and rely on countermeasures, or build rotating sections — has a 10-year development timeline implication.

Nuclear propulsion integration. Nuclear thermal propulsion (NTP) cuts Mars transit time from 9 months to ~4 months (Isp ~900 s vs. ~450 s for chemical). But NTP vehicles cannot dock at a station with a live reactor. A separate "hot dock" infrastructure — a tethered parking node at safe distance — would be required. No current station design includes this.

Autonomous operations during crew absence. Interplanetary launch platforms will be uncrewed for months at a time between missions. Autonomous maintenance, fault detection, and system recovery — demonstrated on the ISS only with continuous ground support — must be proven at a level that survives multi-week communication delays.

Sources: NASA Moon to Mars Architecture Definition Document, Rev C (December 2025) · Vast Space Haven-1 technical specifications (2025) · Essential Moon Framework, Gaviraghi (November 2025) · NASA Fission Surface Power Program status (2024) · NASA Human Research Program annual report (2024) · SpaceX Starship propellant estimates (2024) · CASIS ISS National Lab annual report (2023) · NASA LCROSS mission data (2009, updated 2024)